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N.A.A.S. QUARTERLY REVIEW

NUMBER

34

Winter 1956

London
Published for the
Ministry of Agriculture, Fisheries & Food
by Her Majesty's Stationery Office

PRICE 1*s.* 6*d.*

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QUARTERLY REVIEW

The Journal of the National Agricultural Advisory Service

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LONDON : HER MAJESTY'S STATIONERY OFFICE : 1956

REVIEWS AND ABSTRACTS

In this section of the N.A.A.S. Quarterly Review, it is intended to survey current research and experiment in agriculture, horticulture and the allied sciences applicable to the work of the National Agricultural Advisory Service. It will not be possible, of course, to cover more than a small part of this wide field in each issue.

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Notes on the Planning and Execution of Field Experiments

J. A. NELDER

National Vegetable Research Station, Wellesbourne

IT IS CUSTOMARY to divide research into the categories "pure" and "applied", where the two adjectives are often taken to mean respectively "apparently useless" and "potentially useful". The division, though often convenient, is an oversimplification, since the motives behind research are more complicated than it suggests. For our purposes we may distinguish between experiments to discover why something happens—these we call *fundamental experiments*—and experiments to discover whether something works, which we call *empirical experiments*. Thus, an experiment to test whether a new compound is of any use as an insecticide is an empirical experiment; an experiment to determine how and why the insecticide works is a fundamental one.

These two types of experiments are extreme ones. In practice an experiment may show both aspects, and it is one of the important jobs of the experimenter to decide how much fundamental work should accompany a field experiment. This will be considered more fully under stage 6 below. A vast amount of agricultural experimenting remains very much at the empirical level, but it is not necessarily any the worse for that. For example, there is still very little knowledge available about how dung produces large increases of yield in many crops, but there is no doubt at all that it does so. Nevertheless, there are important limitations to the purely empirical method in applied research. Some of the reasons for this will be considered in the following sections, where we consider the various stages in the planning and execution of an experimental programme. The examples in this article are taken chiefly from horticulture, but it is hoped that the points they illustrate may be of interest to workers in other fields.

Stage 1—A question arises

The original stimulus to research may come from various sources. It may be the sudden arrival or spread of a new pest, a chance observation by a research worker or farmer about the effect of a particular treatment, the desire to try out in this country a new variety produced abroad, plain curiosity about the truth of an old gardening saying, and so on. At this stage, the most important thing is for the experimenter to be sure that he is asking the right questions. Thus, if a new compound is introduced as a source of nitrogen for growing plants, an experiment could be put down comparing the new compound with a control treatment of no nitrogen. But the question that this experiment would answer—does this compound improve plant growth when given as a source of nitrogen?—is probably far less important than questions such

as, is it cheaper, or longer lasting, or quicker acting than equivalent quantities of existing nitrogen fertilizers?

Stage 2—Has anyone already answered the questions?

Generally speaking, it is unusual for there to be a complete lack of knowledge about the subject of the experiment, and to assist him in framing the right questions the experimenter begins searching for and digesting existing literature on the subject to find out the present position. It is often difficult to find the relevant papers, and also to assess how far previous work, which has often been done with slightly different objects in mind, is really relevant to the present question.

Stage 3—What treatments are needed in the experiment?

Such decisions are often difficult. The number of possible treatments which might give useful information on the subject in question is usually extremely large. At the same time the experimenter's resources are usually correspondingly small. Thus, any trial with a fertilizer could involve rates of application, times and frequencies of application, method of incorporation, long-term effects, comparisons and interactions with other fertilizers, effect of irrigation and so on. It is most unlikely that the experimenter's resources will allow him to test all these aspects at once. It is therefore necessary to draw up a list of priorities to help in deciding what should be kept and what discarded in the first experiments.

The final treatments will depend to some extent on how much is known about the experimental material. If almost nothing is known about, say, the cultivation of a new crop, it may be best to incorporate in a preliminary experiment a number of factors, each at two levels, to see on what lines future research needs to be concentrated. The type of design known as fractional replication enables a large number of factors to be tried out simultaneously without the use of an excessively large number of plots. At a later stage, more accurate information will be wanted on certain aspects, and the treatments will be altered accordingly. Some factors will probably be dropped as unimportant, and the levels of others may be changed or increased in number to obtain more detailed information about a certain range of treatments. In annual experiments it is comparatively easy to alter the treatments year by year as suggested by past experience. It is much more difficult to do this with long-term manurial experiments on annual crops, or with experiments on perennial crops. These latter types of experiment demand, therefore, the most careful thought before anything is put down in the field. Thus, where a rotation of annual crops is used, it is most important that it be sufficiently "elastic" to allow for yearly variation in weather, so that the chance of failing to get one crop harvested in time for the proper sowing of the next one becomes negligible. Again, if the levels of fertilizer chosen in a manurial experiment are too high, it may be very difficult to undo their equalizing

effect by reducing them in later years. The reverse process, starting low and increasing if necessary, is quite practicable.

In field experiments another question is continually arising: to what extent should the treatments imitate existing agricultural practice? To take an example: long-term manurial experiments as normally carried out in the field need large plots because, with successive cultivations, the zone where the treated and untreated soils mix at the edges forms an increasingly large border, which must be discarded from the experiment. Often, these large plots do not lead to particularly accurate comparisons of treatments and they are costly to maintain. But they do correspond fairly closely with the normal practice of the farmers and horticulturists who will carry out in the future any new methods of manuring which may be recommended as a result of the experiments. Alternatively, one could use very small plots, each enclosed by walls below ground, and work these plots by hand in as close an imitation of field methods as possible. It is certain that this type of experiment would give much more accurate information about the treatments at a fraction of the cost of the large plots. At the same time, however, the gap between experiment and practice has been widened by the use of such small plots. Unfortunately it is not known how wide this gap is, and there is scope for research to remedy our lack of information on this point. The question of how far treatment differences under experimental conditions will be matched in practice by the farmer cannot be answered merely by considering the experimenter's field technique at a given site.

Stage 4—Where should the experiment be done?

The results of a field experiment are most valuable when they can be generally applied. Every farmer knows that generalization is often dangerous in agriculture; for instance, the variety of cereal that does best in eastern England or with high nitrogen may not do so in the west or with low nitrogen. A herbicide may be safe to a crop in one year and toxic to it the next, and so on. Where treatments or varieties do not behave in relatively the same way under differing environmental factors they are said to interact with those factors.

Generally, there are two ways of coping with this problem. One is to build up a purely empirical body of knowledge, such as by growing the different varieties in different soil types or rainfall areas and noting which is the best in each. Recommendations can then be made for each type of environment. Strictly speaking, such recommendations should be made from experiments done on a random sample of the type of farm for which the recommendation is to be made. Furthermore, the recommendation does *not* guarantee that the recommended variety will be best for *all* farms of the type. It will be best on the average, but it is quite probable that on a few farms it will not be the best. The other way is to try to accumulate enough fundamental

knowledge by experiment to account for the interactions, it being assumed that the generalizing power of such knowledge will be high.

The difficulties of each method are fairly obvious. The empirical approach faces one important difficulty immediately: in practice it is often impossible to put down trials on a random sample of sites; the owners may be unco-operative or the experimenter's staff too small to manage the collection of the data. The result is usually that the trials are confined to experimental stations and perhaps a few, usually the more progressive, commercial holdings. It is uncertain whether such sites will give a representative sample; indeed there are good reasons for thinking they will not. How far the results will be affected by their being unrepresentative is usually quite unknown, and in practice this ignorance is the biggest drawback of the empirical approach. The other approach, that of trying to find out what in the inherent make-up of the varieties is responding differently to different environmental features, might well prove a very long job; so long in fact, that new varieties might come and go before their value could be fully assessed. It seems, therefore, that the answer to the question "where should the experiment be done?" must remain: "in as many suitable sites as resources allow". Nevertheless, the need for fundamental work in interpreting the interactions between sites and treatments remains great.

Stage 5—How should the experiment be laid out?

The branch of statistical theory dealing with the design of experiments is only some thirty years old, but it has had a great effect on the type of layout used in field experiments. All modern designs have three main objects:

(*a*) to measure the effects of different treatments without systematic bias;
(*b*) to reduce variation caused by extraneous factors, e.g., soil fertility;
(*c*) to measure the probable effect of the remaining extraneous factors on the treatment differences.

To bring about (*a*), the device of *randomization* is used. This has the effect of making it equally likely that any treatment will occupy a certain plot, thus ensuring an equal chance for all treatments. For greater accuracy (*b*), various devices have been introduced, the simplest of which are the grouping of plots into blocks, and the use of the Latin square design. Each device aims at cutting down the effects of soil fertility and other unwanted differences which distort the effects that the experimenter is trying to measure. But no matter how successful these devices are, a certain amount of unwanted variation from plot to plot always remains. This constitutes the experimental error, and the object of (*c*) is to express this error in numerical terms. To do this, randomization is again necessary, and also some *replication*, whereby each treatment is allocated to several plots in the experiment. The experimental error is expressed in the form of a *standard error*. When the standard error is known, an estimate can be made of the chance

that the experimental error will distort the real treatment difference by more than a given quantity. Thus, only about once in twenty times will it distort the treatment difference by as much as twice the standard error or more.

Although the theory of experimental design is of undoubted help to the experimenter, it is important to realize what it cannot do. It cannot, for instance, tell the experimenter what basic factors to test (though it may have something useful to say on the way in which they may be combined); it cannot make a badly carried out experiment into a good one, or an unnecessary experiment into a necessary one. Even a rational decision on the number of replicates to be used cannot be made until the experimenter has specified how big a treatment difference is important to him, how certain he wishes to be of picking it up in the experiment, and how big the experimental error is likely to be. Quite often a small pilot experiment provides valuable preliminary information for a more efficiently designed experiment to follow.

A clear distinction needs to be made between an experiment and a demonstration. The two things have, or should have, different aims; an experiment to discover new facts or test new ideas, and a demonstration to show in a vivid way what is already known. It is not surprising, therefore, that they need different kinds of layout, and it is only rarely that an experiment is suitable for use as a demonstration. Conversely, equipment intended for use on a commercial scale may be suitable for demonstration purposes but not for experimental use, although there is often a temptation to design an experiment round it in order to justify the equipment's existence.

Stage 6—What records should be made?

Records from an experiment may be divided into final and intermediate. This distinction is related to the fundamental and empirical aspects of the experiment considered above. Final records are concerned with the end result of the treatment—the yield of the crop, the amount of infestation by a pest or disease at harvest, and so on. Intermediate records comprise all those taken during the growth of this crop, and their object is to shed light on the reasons for the final result. The quantity and type of these intermediate records are only partly predictable, and unexpected effects of the treatments may necessitate collecting data of a type not foreseen when the experiment was laid down. In an experiment it is rarely sufficient to record merely the final yields of a crop. For example, if one variety in a trial suffers considerable loss from a late frost while another does not, this loss may well produce a large difference in final yield. The value of the final result is much greater if intermediate records are available on the amount of frost damage at the critical period. Again, consider an experiment to determine the effect of various insecticides applied at various times on some pest. It may be found from the final yield or from final counts of unattacked plants, that a certain treatment has been

successful, but it is quite possible that this result would not occur in the next year. If, however, counts of the numbers of the pest had been made at regular intervals, the results might enable the experimenter to say that the most successful treatment had been an application of so much insecticide X days after the appearance of the first adult flies. It is likely that the instruction "apply G g of insecticide X days after the emergence of the first adult flies" would be a much more valuable interpretation of the experiment than "apply G g of insecticide on 10th May": "Valuable" here means "more likely to apply generally to other sites and in other years".

Records which give the experimenter an insight into why, where or when his treatment differences have occurred, increase the value of an experiment both to him and to others wishing to make use of his results.

Stage 7—Field work

Experiments are made or marred more than anything else by the field technique of the experimenter. Firstly, he must be able to grow a reasonable crop, or arrange for this to be done. Results obtained on an abnormally poor crop may not be applicable to average or good crops. Secondly, he must be aware that the way in which he carries out cultural operations may bias the results of the treatments or increase the experimental error, and thirdly, he must be able to take accurate records from the plots.

Sufficient basic information is usually available nowadays to allow a reasonable crop to be grown for the experiment, although frost or a hard winter may upset the plans. Similarity of cultural or harvesting methods are very important, otherwise various difficulties can arise, some obvious and some more subtle. For example, it is obvious that in a cauliflower experiment, plants in one treatment should not be cut by one person, and those in another treatment by someone else; if this is done, differences between the cutters' assessment of maturity become mixed up with treatment differences and cannot be separated. The golden rule here is: *do everything by blocks*. Thus, with an experiment on a transplanted crop, let each planter transplant a whole block or blocks, and do not let the faster worker help the slower one to finish off his block. Hoeing is best done by blocks if there is more than one worker, because hoers vary greatly in their efficiency in removing the weeds, and in the amount of damage they do to the crop. Again, at harvest time, if more than one cutter is required, confine each to a whole block. If the crop for any experiment cannot be planted, sown or harvested in a day, aim to finish a number of complete blocks each day. If multiple harvests are necessary for a crop (e.g., tomatoes, cauliflowers, etc.) it is essential for the same cutter or picker to continue on any block throughout the harvest unless his successor can be guaranteed to have the same standards of assessing maturity.

Other decisions about the field work may not lend themselves so easily to rule. Suppose that in a spacing experiment, the closely-spaced

plants in the half-grown crop show clear symptoms of nitrogen shortage while the widely spaced ones do not. What should the experimenter do? Put no more nitrogen on any plot, and deliberately allow poor conditions of growth to continue on the closely-spaced plot? Or put nitrogen on all plots, in spite of the fact that some do not appear to need it? Or give it to those plots showing obvious need? If the plots are big enough, it may be possible to split them into two and give nitrogen to one half only, thus obtaining additional information on the effect of the nitrogen level on the yields from different spacings. Otherwise, it may be necessary to dress all the plots for that year and decide to incorporate nitrogen level as an additional treatment in the following year.

The third course—to give it to those plots showing obvious need is, however, most dangerous. A skilled gardener by applying "subsidiary" treatments in this way can often nullify the effect of the original treatments. The results prove nothing except his skill in gardening, yet it is surprising how many experiments have been ruined in this way.

Too much thought can hardly be given to devising a foolproof way of taking records. For when all the field work has been done, usually nothing remains but figures and notes on paper, and it is a great waste of effort if these do not represent accurately what has happened. Carefully drawn up record-sheets are invaluable and these should allow room for any unforeseen but useful data. If records can be given in a quantitative form, amenable to analysis, so much the better. Thus, a reasonably objective scale of infestation by a pest, perhaps with categories numbered 0 to 5, is preferable to a set of remarks such as "light", "severe", "very severe", and so on.

Stage 8—Analysis of the results

When all the records have been collected, their interpretation can be attempted. The first stages in this process will be the picking out of interesting features of the results and their analysis. The interesting features may have been known before the experiment started or they may appear in an unexpected fashion during the experiment. A field experiment is often designed to measure yield, amongst other things, yet the appearance of an unusual pest in a variety trial will give unexpected information about its effect on the various varieties. The numerical analysis consists mainly of evaluating treatment means and measuring their accuracy in the form of standard errors. The latter part is often rather specialized and is usually the statistician's job, but the experimenter should decide what quantities (yield, infestation percentage, and so on) to analyse.

It cannot be too strongly emphasized that there is no one analysis which is right for an experiment. What an experimenter gets out of an experiment depends on his knowledge of its subject and his acuteness in asking pertinent questions of the results. (It is quite possible for an interesting aspect of some experimental results to go quite unnoticed

by the experimenter and be pointed out by someone else.) The position of the statistician at this stage is often an ambiguous one. On the one hand, his experience in coping with large amounts of numerical data may make it easy for him to pick out salient features quickly and to assess the reliability of the results; on the other, his lack of detailed knowledge about the subject of the experiment may lead to a false emphasis on certain parts of the results or to a neglect of some important feature. He is more concerned with means than ends, and the experimenter should always be the final assessor of his own results.

Stage 9—Making a report

This is the final stage. A single experiment may be written up just for the experimenter's benefit and the results go no further. Usually it will be written up as one of a series of experiments on the same subject. Again, the experimenter may decide not to publish the results, but to circulate them as a report of limited distribution, or to publish them in the form of a paper or article for publication. The paper will contain the reasons for the experiment, how it was done, what the results were, and the experimenter's views on the implication of the results. The raw material for the paper is, of course, chiefly the data from the experiments combined with any past data from other sources. The statistical analyses will form an objective basis for the discussion of the results, but only a basis, and the final assessment will necessarily be partly subjective and coloured by the experimenter's beliefs and prejudices. It will be none the worse for that, and none the better for being written in the passive mood or with the experimenter heavily disguised as "the present writer". Writing scientific papers is not an exact science, neither is the interpretation of experiments. The absence of hard and fast rules for either is perhaps one reason for the all-too-common appearance of papers cluttered with irrelevant facts and muddled thoughts about their interpretation. It is always difficult to strike the right balance between the presentation of facts on the one hand and ideas about their meaning on the other. One thing is certain; facts alone are not enough, and a catalogue of these may contribute less to understanding than one bright idea.

Estimating the Frost Risk of an Orchard Site

E. N. LAWRENCE

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THE APPLICATION of a method [1] of estimating the mean frost frequency of an orchard site at Luddington Experimental Horticulture Station was described in this REVIEW three years ago [2]. Although mean frost frequency is a useful indicator of the local economic frost risk, it is probably more helpful to know the frost risk on a basis of how many years in say, ten, that a frost of a given severity occurs. For it is obvious that one killing frost in each of two years is economically worse than two in one year, followed by a year without a killing frost, although in each instance the annual mean frost frequency is one.

A method has been described [3] for calculating such frost risk possibility. The procedure is briefly as follows. In the area under survey, night minimum temperatures (at a height of 4 ft above ground) are observed over a suitable network of points during the frost season (April and May) for at least one year. From these observations can be obtained:

(*a*) the average daily minimum for each week (averaged over the seven nights);
(*b*) the extreme minimum for each week.

If observations are taken for two or three years, the value for (*a*) is obviously the average of fourteen or twenty-one nights, and for (*b*) is the average of two or three values respectively. Unless these figures for one or two years can be "converted" into long-term values they are of limited use. For conversion, the measurements are weighted by reference to contemporary and long-term records of a nearby weather station. This means that if the weather station temperature for a particular week is one degree above its long-term average for that week, then one degree is subtracted from the site temperature for that week to obtain what is called the "weighted average" (long-term) of the site. In practice, a nearby long-established station in the same general climatic regime is often not available and it becomes necessary to "weight" the short-term records of the site by reference to the mean divergence from long-term average, found from a network of established meteorological stations in the neighbourhood.

After "weighting", these sets of weekly temperatures are plotted on a temperature-time graph, and through them are drawn smooth curves which conform in shape to the known normal rate of increase of minimum temperatures with time of year. For convenience in this "smoothing", the graph paper used is printed with guide curves of the normal shape. The smoothed curves now enable close estimates to be made of:

(*a*) the long-term average daily minimum temperature for each week;
(*b*) the long-term average extreme minimum temperature for each week.

The difference between these values gives the site spread coefficient (s) for the week. From these details it is now possible to estimate the frost risk for each week of the period.

If an assessment of the *monthly* risk is required, smoothing is effectively carried out merely by averaging weighted temperatures for appropriate weeks, which will give an answer similar to that obtained by the graphical method. To obtain the frost risk for, say, May, the values of (s) (averaged over the weeks in May) and the value of the mean daily minimum temperature for the month ($\overline{T}$) are substituted in the following formula:

$$R = (\overline{T} - T - bs)/cs$$

where b and c are area constants based on climatological data of nearby long-established meteorological stations* and T (for example 28°F) is the given extreme minimum temperature whose frequency is required. Having calculated the value of R, the given extreme minimum temperature T is reached once in t years, where t is given by Table 1[4]. To obtain intermediate values of t, the figures of Table 1 should be plotted and the resulting graph of R against t used for this purpose.

Table 1

Values of R for computing the frequency (once in t years) when an extreme temperature (T) is likely to be reached

t	1.58	5	10	25	50	100
R	−0.39	0.79	1.34	1.85	2.19	2.47

This technique was applied to the problem of ascertaining the frost risk on a proposed orchard site at Rosemaund Experimental Husbandry Farm, Preston Wynne, Herefordshire. Minimum temperatures were observed daily throughout April and May 1954 at the four sites shown in Figure 1. The four sites were in a valley, site 2 being the lowest and sites 3 and 4 on a slight slope. Sites 3 and 4 were situated in an old grassed orchard (see Plate I), while sites 1 and 2 were on open grassland. The soil type here is old red sandstone (Bromyard series). The "May" data are shown in Table 2.

*Actually b is the mean value of the ratio of the monthly spread coefficient to the weekly spread coefficient for the region, conveniently obtained graphically. C is the ratio of the standard deviation of May mean daily minimum temperature to the weekly spread coefficient for a nearby established station, and is, in practice, often obtained by averaging over a network of stations.

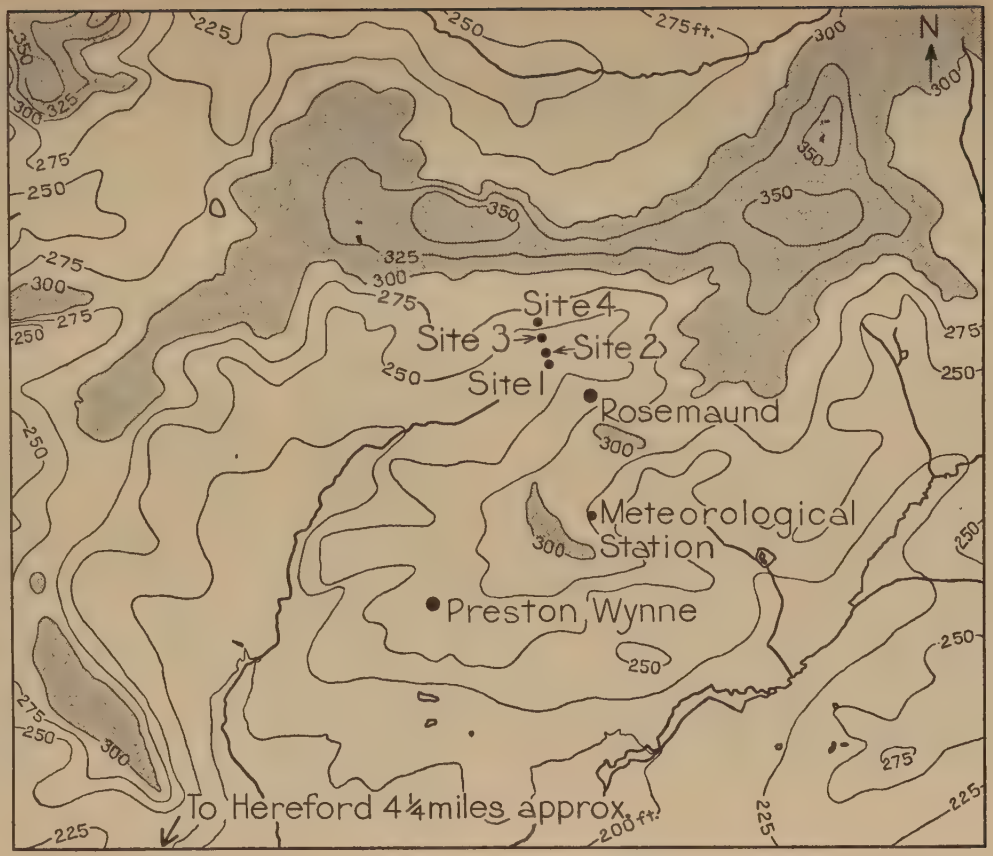

Fig. 1. Minimum temperature recording sites at Rosemaund Experimental Husbandry Farm, Preston Wynne.

Table 2

Temperatures at Rosemaund (°F)

Site 1	Site 2	Site 3	Site 4	
Week ending	39.0	35.7	38.9	40.0	Average daily minimum
May 6th, 1954	34.4	31.0	34.2	35.4	Lowest minimum
	4.6	4.7	4.7	4.6	Weekly spread coefficient
Week ending	40.8	37.3	41.7	43.0	Average daily minimum
May 13th, 1954	30.4	27.0	31.4	32.9	Lowest minimum
	10.4	10.3	10.3	10.1	Weekly spread coefficient
Week ending	41.9	38.0	42.3	43.0	Average daily minimum
May 20th, 1954	31.8	27.6	33.1	34.0	Lowest minimum
	10.1	10.4	9.2	9.0	Weekly spread coefficient
Week ending	47.4	42.9	47.3	48.2	Average daily minimum
May 27th, 1954	42.7	38.8	42.7	43.7	Lowest minimum
	4.7	4.1	4.6	4.5	Weekly spread coefficient
Averages	42.3	38.5	42.5	43.5	Average daily minimum
"May", 1954	34.8	31.1	35.3	36.5	Average weekly minimum
	7.45	7.4	7.2	7.05	Average weekly "spread"
"Weighted" averages	41.4	37.6	41.6	42.6	Average daily minimum
(long-term)	33.9	30.2	34.4	35.6	Average weekly minimum
May, 1921-50	7.5	7.4	7.3	7.1	Average weekly "spread"

The "weighting" of the observed averages to obtain long-term values was based on a network of several established stations in the region. The area values of b and c were taken to be 1.79 and 0.47 respectively. The values of R were then calculated from the formula, and the values of 10/t (that is the number of years in ten with a given extreme minimum temperature of T or below in "May") thus obtained, using the values of t from Table 1 and graphical interpolation. The results are given in Table 3.

Table 3

Number of years in Ten with a Minimum Temperature in "May" of T or Below

T(°F)	Site 1	Site 2	Site 3	Site 4
32	> 5	> 5	> 5	> 5
30	> 5	> 5	> 5	5
28	5	> 5	4	2–3

The method for obtaining mean frost frequencies was also applied to these sites at Rosemaund, and the results given in Table 4, which includes also the corresponding frost frequencies at some standard meteorological sites. The latter was based on data given in an earlier paper [5].

ROSEMAUND EXPERIMENTAL HUSBANDRY FARM

Top : Site 3, looking north.
Bottom : Site 3, looking south.

PLATE I.

Table 4

Estimated May Frost Frequencies (per Ten Years) at Rosemaund. Some Observed Values

T(temp.°F)	Site 1	Site 2	Site 3	Site 4	Ross-on-Wye	Belmont Abbey (Hereford)	Park-end (Glos.)	Strat-ford-on-Avon	Droit-wich
32 or less	33	71	29	22	9	14	23	21	35
30 or less	22	49	18	13	4	5	13	12	21
28 or less	11	31	9	7	1	3	4	8	13

When considering the results in Tables 3 and 4, it must be remembered that the sites are not all strictly comparable. Sites 3 and 4 were under trees in the old grass orchard and consequently were more like the proposed orchard site than sites 1 and 2 over open grassland. If the new orchard is similar in vegetation cover, cultivation, etc., to the old one, and if a screen temperature of 28°F or below (at 4 ft above the ground) is the critical temperature for frost damage in the trees above, and if three years in ten is the permissible economic frost frequency, then the results in Table 3 suggest that site 4 is a fair economic risk, while site 3 is unfavourable, or at the best a border-line site. Further, from contour considerations, it is most probable that sites 1 and 2 are frostier than sites 3 and 4, assuming vegetation cover, etc., the same for all sites. This reasoning leads to the conclusion that sites 1 and 2 are poor economic risks.

The author would like to thank the staff of Rosemaund Experimental Husbandry Farm, Preston Wynne, Herefordshire, for their co-operation and, in particular, for making the observations. Much valued help has also been received from Mr. Duggan, Horticultural Officer, N.A.A.S., Hereford, in this and other similar local investigations. Without such co-operation, help and practical advice, experiments of this character could not be carried out.

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Reading and the Advisory Officer

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A SHORT TIME AGO I was asked to give an opinion on a small library of agricultural books which had been willed to the son of a prominent farmer in this county. It was an unusual piece of advisory work, but since the legatee was an intelligent young man of twenty our discussion ranged over a far wider field of reading than was covered by the volumes to which he had become heir. One question which he asked me was "What books have you found to be most useful in your capacity as an Advisory Officer?"

In trying to answer the question, my mind went back to University days when the paramount need was to pass examinations. Facts in profusion were then vital, and the more one knew the more one was likely to achieve the magic letters of B.Sc., or N.D.A., or the like. I read a few text books that interested me, and many that I forced myself to read. The after-effects of this cramming, of forced mental feeding, was such that for years after leaving the University I rarely looked at an agricultural book of any kind. Then came the war years, to be succeeded by service in the N.A.A.S. During that time, I read a lot of non-agricultural books, hardly to be called "literature"; but, agriculturally, the weekly farming papers and the Ministry's Journal seemed to be adequate. Then, in 1948, came my present post and it is from that time that the period of fallow ended, possibly because the job meant some release from matters of detail, and with it came the need to broaden one's mental horizon.

From " Piecemeal " to a Pattern

Modern farming is complex, and the ever-increasing tempo of agricultural research is making it more so. As a result, the amount of factual information which advisory officers are expected to possess, or be able to find, is growing rapidly. But, if he is to be well-informed and up-to-date, it is not enough for the advisory officer to make himself a store house for a large number of isolated and often disconnected facts. He must be able to fit them in to the sequence and pattern of nature, in which the past is inexorably related to the present. Otherwise, the harvest of information gathered over the years will be of little value. But first, the form and scale of the intricate evolutionary pattern must be discerned, and to this end, reading beyond immediate technical needs appears to be an essential part of one's full training. It can only be done in the few private hours that we have, and it is natural that individual tastes will vary enormously. One man's meat may be another's poison. It is extremely doubtful, therefore, whether there can ever be anything in the nature of a recognized course of reading. Furthermore, views now held may very well alter in future years. Even at present,

the field of literature is so extensive that we can never hope to be conversant with more than a fraction of it. A certain amount of self-control in the choice of books is therefore necessary. In my own case, this has meant some degree of specialization, an undesirable thing in many ways, but it is difficult to see how it can be avoided, if reading is to be of some direct use.

For my own part, this specialization has been primarily in the fields of agricultural history and primitive farming, but in recent years the attraction of writers with a philosophical approach to agricultural science has been very strong. The distinction between the historian and the philosopher is at times somewhat arbitrary, but it is convenient to make this separation for the purpose of some degree of orderly discussion.

Agricultural History

By chance I happened to come across Macdonald and Sinclair's *History of the Hereford Breed*, which is a classic of its kind. One thing usually leads to another, and in this case it was perhaps natural to seek further information about the entry and spread of Herefords into Breconshire. The problem was where to find it. It was suggested to me by a very eminent, but recently retired, member of our Service, that a study of the first and second official reports on agriculture, issued by the Board of Agriculture in 1794 and 1815 respectively, might be worth while. And so they were, to the extent of providing almost precise dates and geographical distribution. It seemed that Herefords crossed the border about 1790, but by 1815 they and their crosses had become the predominant breed. These two reports certainly fall within the last part of Bacon's dictum:

> "*Some books are to be tasted, others to be swallowed, and some few to be chewed and digested.*"

This glimpse into the past, and its association with the prevailing system of breed and cattle husbandry, stimulated an interest in other sections of agricultural history of the county. Without having anything particular in mind, I began to gather bits and pieces, but concentrating on the period after about 1730. This seemed to be the beginning of the present age in farming. There is no point in listing the various sources of information since they are only of local interest; it is sufficient to say that what had been spasmodically read became extremely useful for publicity purposes in 1955, on the occasion of the 200th Anniversary of the founding of the Brecon Agricultural Society.

The Society, in its long life, has been energetically concerned with every aspect of farming in the county, such as livestock, machinery, and the cultivation of root crops such as turnips, swedes and mangolds. Just as a study of the developments initiated by the Society had to be fitted into the general farming background of the county, so this in turn created a desire to know more of the history of farming throughout

England and Wales. For instance, knowing that the Society awarded premiums for potato growing in 1757, led me to read R. N. Saloman's classical work *The History and Social Influence of the Potato*. Again, the earliest known reference in the county to swedes, or "swedish turnips" as they were then called, was in 1814; this led me to search for facts about the introduction of this crop into Britain. Wood's *History of the Royal Society of Arts* is one of the less well-known books, but it is full of meat on the early history of crops in this country.

It would be tedious to list the array of books dealing with the development of British farming, but three which I liked immensely were Arthur Young's *Tours and Annals*; Scott Watson's *Great Farmers* and more recently Nigel Harvey's *The Farming Kingdom*. The need to know something of the history of farming has been clearly expressed by Harvey:

> "*The modern farm is only the latest stage in a long and continuing process of development and so cannot be assessed solely in terms of the present. Today, for example, the combine harvester works in the field pattern established by forgotten Enclosure Commissioners of George III's time. . . .*"

Primitive Farming

If one wishes to delve a little deeper, and to broaden the base of one's farming knowledge, then primitive systems of agriculture as described by Professor Daryll Forde in *Habitat, Economy and Society* are worth studying. Closely allied to this are the all-too-few studies of wild animals. Two of those in particular, have a bearing on modern hill sheep husbandry. The first is Dr. Fraser Darling's *Herd of Wild Deer*; the author is a notable example of a biological scientist who makes the animal as a whole and animals in their social communities the main object of interest. His fellow countryman, Dr. Allan Fraser, acknowledges the value of this approach when he says in one of his own books, *Sheep Husbandry:*

> "*If science wishes to be of more immediate and greater use to sheep farming than it has been in the past, the places to study should therefore be the places where sheep live—the hills, the deserts, the plains, the fields.*"

The second is *Reindeer Are Wild Too*, by Miss Joan Newhouse. This is more of a geographical study, but it describes in a fascinating way the relationship between the Lapps and their animals:

> "*But even if I had continued to live with them for many years I could never have achieved that complete negation of self and recognition of the supreme importance of the reindeer, which is the secret of the Lapps' survival; but this surely no non-Lapp can do.*"

The other conclusion that can be drawn from this book is that general purpose livestock, like the reindeer, fit the needs of the subsistence and pastoral farmer best. It is only when farmers become commercial, trading surplus livestock produce, that livestock specialization towards one particular product or purpose becomes worth while.

The Philosophical Approach

Agricultural literature is now so complex and specialized that the primary need is to find a way through the maze of detail to fundamental scientific facts. As an old student of Agricultural Botany, I had long been aware of photosynthesis, but until I read *Research for Plenty* its significance to farming had really escaped me. But to be told that it is:

> "*the central process of life whereby the free energy of sunlight is stored in the plants of the earth for man and animals.*"

was an exciting introduction to this booklet published by Geoffrey Bles in 1953. The effects of this "central process" are then discussed from eight biological points of view—those of the agriculturalist; the botanist, the plant physiologist, the soil scientist, the physiologist, the zoologist, the fishery expert and the biochemist. One hesitates to dogmatize on choice of reading, but if ever there were a "must" then it is *Research for Plenty*.

Grassland is now a fashionable field of research and advisory work, and therefore the thoughts of Sir George Stapledon—of ley farming and grassland management fame—are particularly significant. His book *The Way of the Land* is really a series of separate papers and lectures delivered to various bodies between 1912 and 1942; each paper reveals a breadth of mind and standard of culture which is nothing less than staggering. His approach to literature is:

> "*Do not read like a scientist looking for information, for facts to pigeon-hole in your over-stocked and under-nourished brains. Read to get the atmosphere of what you are reading about, read to grasp the point of view of your author, try and see behind your author's words and phrases. If you will but read properly, literature more than anything else in this world will help to make you a man of good judgment.*"

This summer I spent a few weeks in Spain, probably at the present time the most interesting, agriculturally speaking, of the European countries. Before going there, I had read a little of the history of Merinos and of the system of seasonal migration, called transhumance, which is associated with the Merinos of Spain. But to have seen, some 6,000 ft up, a flock with its shepherd, who spends the summer in the high mountains before returning to the lowlands in late autumn, gave tremendous significance to what I had read about primitive pastoral life. It was satisfying, too, to be able to explain to others the reasons why Spain had imported Santa Gertrudis cattle, and to know the place of origin (King Ranch, Texas), and the breeding and circumstances which created this breed. The fat-tailed Karakul sheep were living examples of the most extreme form of animal adaptation, developed in an environment of marked seasonality of plant growth. Then there were the fighting bulls, of a specialized breed developed and selected simply for their ferociousness. The moral behind this paragraph is not so much to relate the outstanding advantages of seeing at first hand an agricultural economy less advanced than our own, as to draw attention to I. L. Mason's *A World Dictionary of Breeds, Types and Varieties of Livestock*. It is a useful book to take when you go abroad.

Reviews and Abstracts

Agricultural Pest Assessment

II—A Partial Solution

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In Part I [1] it was stressed that the lasting value of pest assessment work lay in the better understanding of pest ecology which emerges from a careful study of properly documented field data. This article describes the work which has been done by Advisory Entomologists in England and Wales since the war, and shows how their approach is shedding a new light on the basic problem of pest damage and control.

A FULL APPRECIATION of an insect pest demands a combination of laboratory and field work extending over a period of years. Intricate laboratory investigations, and some aspects of the field work, are clearly the province of workers at Research Stations and in University Departments. But in economic entomology, just as in plant breeding, it is essential to replicate observations over many sites if conclusions of general validity, applicable to the country as a whole, are to be obtained. Unless the incidence of an important economic pest is confined to a small area, it is impossible to expect a single research station, or even the entomologists in any one N.A.A.S. province, to make an adequate study of its distribution and abundance on its host crop throughout England and Wales. Co-operative work is necessary, and the N.A.A.S., with representatives all over the country, is certainly the best fitted, and probably the only organization able, to do the work.

A Dual Approach

The Advisory Entomologists have approached pest assessment problems from two points. First, work was started on a quantitative survey basis. Routine estimates of the annual peak densities of a number of pests were made at about 100 sites distributed largely at random throughout the major host crop growing areas in England and Wales. The results not only provide information on the distribution and abundance of the pests within the country as a whole in any one year, but also enable comparisons to be made between one year and the next. With bulked results of this type, it is possible to begin investigating the relationships, if any, between pest densities and meteorological conditions, both over the country as a whole, and within limited areas, in which the conditions under which the host crops are grown are contrasted. Such work can lead to the development of an outbreak forecasting service as, and when, the meteorologists develop accurate long-term weather forecasting.

The second avenue of approach has been through two types of detailed field plot experimentation. It has been developed along intensive and extensive lines appropriate to the problems demanding attention. In work on rabbit damage [2, 3], for example, a large number of very simple experiments were made on a random sample of about 200 cereal fields on farms all over the country, while work on Cabbage aphid [4] and Frit fly required intensive work on a much smaller number of complex experiments—about one such trial per province or sub-province. In both types of trial, the pests under investigation were excluded from certain of the plots, while on others they were allowed to behave naturally. Routine estimates of pest density were made throughout the crop season, and finally all plots were carefully harvested so that accurate yield data and information on pest numbers were obtained. It has thus been possible recently, and for the first time anywhere in the world, to relate yield of marketable produce with pest numbers throughout the growing season over the country as a whole. The implications of this approach are best appreciated through a concrete example, and the results on Cabbage aphid and Frit fly will serve the purpose.

Cabbage Aphid Investigations

In 1946, an extensive survey of peak Cabbage aphid infestations on Brussels sprouts was made and followed up by a survey of overwintering eggs and live aphids in January 1947. A ranking system was used in the peak survey, plants being classified as "clean", "slightly", "moderately", or "severely", infested according to a visual estimate of the number of leaves and sprouts with aphid colonies on them, while actual counts were made of the relatively small numbers of overwintering forms found in the January survey. These two surveys were made annually until 1951 [5], when it became clear that the winter counts were of little value and it was decided to discontinue them. The peak survey has been maintained, and we now have ten years' complete data on Cabbage aphid population fluctuations based on an average of 100 randomly selected, unsprayed sprout fields per annum.

Work was extended in 1951 to include intensive field plot work in which the plants on half of the plots in a simple randomized block experiment were kept free, or substantially free, of aphid by regular treatment with a selective insecticide, while on the rest of the plots aphids were allowed to build up naturally. Aphid density counts were made at regular intervals on all plots, and at the end of the season yields were assessed by harvesting which was carried out by professional pickers who were asked to pick only those sprouts which they knew to be commercially marketable under prevailing conditions. Two pilot trials of this type were carried out in 1951, the experience gained being used to introduce a simplified scheme which was subsequently put in hand on many sites. This work was continued for five seasons, at the end of which we had accurate data from 20 trials in all the main sprout-growing areas, under a variety of cultural and climatic conditions.

Insect damage can be looked upon as a product of time and of pest density. Obviously, if a group of small caterpillars are removed from a cabbage plant when only a few days old their effect on final yield will be less than if they are allowed to continue eating the host tissues for several weeks, especially if, during this time, further eggs hatch and the density of caterpillars increases. It is therefore unsound biologically to interpret yield reduction in terms of a single pest density measurement made at only one stage in the growth of the host plant. If the pest increases in density in proportion to the size of the maturing host, it is essential to consider the growth of the pest and its host at least twice, and preferably more often during the season, for a fair interpretation of yield reduction.

This has been done in the Cabbage aphid work by computing a multiple regression analysis. Yield of marketable produce was related to aphid density 6-8 weeks after the young plants were established in the field, and again at the time of peak aphid density which usually occurs 12-14 weeks after the plants have been set and when they are approaching maturity. It is clear from this analysis that the quite small numbers of aphids which are usually present on sprout plants from the seed-bed stage up to about the middle of July, cause a yield reduction which is equal to nearly half the total loss caused by infestations which persist until October, when populations normally decline. Brussels sprout crops are normally sprayed commercially at the end of August, when aphids are often sufficiently abundant to attract the grower's attention. Spraying at this time will generally pay for itself in the form of increased yields, but the increase will not be as large as it might have been had the plants been kept free of aphids during the early part of the season. The Advisory Entomologists are now able to recommend early chemical treatment, and, what is of equal importance, they can with some confidence say whether or not a field is worth spraying immediately, though such forecasts are probably only valid for a week or two.

Aphids Loss Estimates

The extensive survey data has been collected in terms of numbers of plants falling within the four ranks already mentioned. From work extending over three seasons it has been possible to give each rank an average numerical value. This has enabled the field survey data for the years 1946-55 to be interpreted in the light of the field plot experiments, in which aphid densities were assessed accurately. There are large errors in the conversion of ranked data to logarithmic values, and the errors of our final estimates of yield loss in Brussels sprouts are correspondingly large. However, it is now clear that Cabbage aphid has, over the past ten years, cost the sprout grower between £$\frac{1}{2}$ m. and £$1\frac{1}{4}$ m. per annum, the average annual loss being £868,000. In acreage equivalents this means that the aphid annually destroys the marketable yield of about 7,500 acres.

A further practical application of results from co-operative field plot and survey work is emerging from the data on Pest Incidence Report

forms [6] which were introduced in 1952. These have been used largely in extensive survey work in which a fairly precise estimate of pest density is made in each field visited. The ecological characteristics of the fields are noted on a questionnaire which is then used as an aid to interpreting the survey results. We know now, for instance, that irrespective of intensity of brassica growing, topography, and other characteristics, there is less aphid damage on sprouts grown in small fields than on those grown in fields exceeding five acres in size. This advantage amounts to about 50*s*. per acre. This is probably not enough to induce a large grower to change his established cultural practices, but might encourage some farmers to try drilling a few rows of a cereal at appropriate intervals in order to break up large fields of sprouts. A similar, quite independent, suggestion has recently been made [7] for the control of virus in brassica seed-beds. We also know that to grow sprouts in fields well isolated from other cultivated brassicas is worth about £8 per acre in the form of reduced aphid damage. Although this estimate is unlikely to influence many farmers to change their established routine, at least they can weigh up the advantages and disadvantages in cash terms before coming to a decision.

Results of this type cannot be obtained without rather detailed information on some hundreds of commercial crops over a period of years—among other things the dangers of false correlations have to be investigated—and in an attempt to acquire a great deal more information, a much simplified report form has recently been introduced. This consists of a 6 × 4-in. Paramount-type punched card which can be quickly completed by the non-specialist. District Agricultural Officers in more than one province are co-operating in completing these cards for a variety of pests in the normal course of their advisory visits.

Frit Fly of Oats

Our work on Frit fly has followed much the same lines as that on Cabbage aphid. An extensive survey of damage to grain by second generation flies has been carried out every year since 1946, and some data are also available on first generation attack in the tillering crop for nine of the ten years. Field plot experiments were started in 1952, and the fifth, and final, year's work has just been completed. Pending analysis of the full five years' trial results, it is not advisable to attach confidence limits to our estimates of overall loss. However, it appears that Frit costs the farming community about £10 m. per annum at the average grower's price of 20.8*s*. per cwt. This yield loss has never really been appreciated, because it is mostly the result of rather low pest densities. Severe Frit attacks—say 30-40 per cent loss of shoots—are the exception rather than the rule. In all, there seems little doubt that oat yields could be increased by about 6 cwt per acre if Frit were to be completely eliminated. However, since this pest is never likely to be completely controlled, it is perhaps better to say that if it could be reduced to about half its present density, the average oat yield could probably be increased by about 3 cwt per acre.

As with Cabbage aphid, the work on Frit is giving the Advisory Entomologist a better appreciation of the nature of its damage. At low population densities, for example, about 60 per cent of the total loss is due to grain damage by the second generation, while at high densities, the picture seems to be reversed—shoot attack may result in twice the yield loss caused by second generation grain attack. The practicability of chemical control on commercial crops is under investigation at present.

Slug and Wireworm Damage to the Ware Potato Crop

Work has been done on wireworm and slug damage to the ware potato crop for the last three seasons in collaboration with the Potato Marketing Board Crop Check Inspectorate. The work is based on an annual sample of about 3,000 main-crop potato fields in England, Wales, and Scotland, and considerable weight can thus be given to the results. One interesting point which has emerged is that apparently the two pests tend to occur on different fields, and the damage they cause is to some extent additive. Damage by both pests in England and Wales amounted to approximately 2.5 per cent of the ware crop in 1954, and 1.2 per cent in 1955. This means that if both pests had been completely controlled the potato acreage could have been reduced by 11,900 in 1954, and by 5,700 in 1955, without affecting the quantity of ware available for human consumption. It is difficult to express this loss in financial terms because pest-damaged ware is valuable as stock feed and is also used in commercial alcohol production.

As well as information on pest damage, data were collected in 1955 on the extent to which insecticides were used commercially for wireworm control in potatoes. Apparently, nearly 40 per cent of the potato fields in south-east England and about 25 per cent of the West Midland acreage were treated with insecticide or insecticide-fertilizer mixtures in that year. Precise information on the distribution of pest damage, particularly if related to the use of insecticides, is of real value to the Advisory Entomologist, not only in formulating local advisory policy, but also in emphasizing the need for local investigations in specific cases.

Work on Other Pests

Before long term co-operative schemes such as those on Cabbage aphid and Frit fly can be put in hand, a careful appraisal of available information on the pest has to be made. Usually it is found that nothing is known about certain aspects of its biology, an understanding of which is essential if the work is to proceed along sound lines. Information on the distribution and abundance of the species within and between individual host plants within fields is frequently not available, and has to be obtained by pilot field investigations before large-scale work can be started. This pilot work is done by the pest assessment team at the Plant Pathology Laboratory in collaboration with workers in one or two provinces who may be particularly interested in the pest in question. For the past three seasons, for example, experiments on the Wheat Blossom midges have been carried

out at Harpenden and in the Northern province, while preliminary work on clover pests was carried out in the Eastern [8] and South-Eastern (Wye) Provinces and has subsequently been developed at Harpenden. This work is now at a stage where it seems likely that a much simplified form of trial can be recommended for general use in those areas where appreciable quantities of clover seed are grown. Similarly, pilot work on Mangold fly is being carried out at present by the entomologists at Aberystwyth, Cardiff, and Derby.

Implications of the Work

Entomologists are generally agreed that insect pests are never likely to be eliminated by insecticides. As Kennedy has pointed out [9], a permanent solution to the problem of pest losses demands a biological rather than a chemical approach. It is only through detailed long-term studies that those factors which influence the natural rate of increase of insect pest species in the field will be understood, and it is only through understanding them that the practical possibilities of their manipulation will become apparent. It is clear, for instance, that Cabbage aphid fecundity is low in areas of high humidity [10]; there is also a suggestion from our survey work that aphid density decreases as altitude increases [6]. It is obviously impracticable to recommend that susceptible crops be grown at altitudes exceeding 300 ft, and mainly in the west of England, which has a higher rainfall than the eastern counties, or within five miles of the coast if they must be grown in the eastern counties. But this is far from saying that other, quite practical suggestions will not emerge from the survey work in course of time; suggestions which may lead to a permanent reduction of pest damage without repeated, or with much reduced, use of expensive insecticidal chemicals.

Such would be a partial solution to the insect pest problem. A complete answer may never be found; but at least the approach made co-operatively by the Advisory Entomologists and their colleagues in the N.A.A.S. has the merit of being biological; further, it is easier to see the practical advantage to be gained by adopting advice based on pest ecology when, in a few cases, probable yield increase or hard cash saving can be stated.

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Minerals in Nutrition

THE VALUE of including herbs in pastures has been the subject of some work reported from Newcastle [1] where plots were sown with a Cockle Park mixture to which varying amounts of herbs were added. A botanical analysis after establishment showed that the components varied from 56.6 per cent grasses, 14.2 per cent clovers, 21.9 per cent herbs and 7.3 per cent miscellaneous weeds in plot 1, to 74.5 per cent grasses, 16.3 per cent clovers, 0.0 per cent herbs and 9.2 per cent weeds in plot 4. The herbs in plot 1 were plantain (15.0), chicory (2.6), yarrow (2.6), sainfoin (0.6) and burnet (1.1). Five cuts taken during the season, using the cage technique, showed that plot 4 yielded a significantly greater amount of dry matter than did plot 1, but on the other hand, the seasonal mean percentages of calcium, phosphorus and magnesium all rose as the herb content of the sward increased. Copper and cobalt content was higher when more herbs were used, but sodium and potassium showed no significant differences.

Small areas of the various plots were used to produce hay and aftermath. There was some sign that hay from a mixture containing herbs had a higher percentage of the major elements, but the effect on the minor elements was inconclusive. The plot with the highest proportion of herbs gave the smallest yield of hay, and trials with sheep showed that the digestibility of protein was less.

Thus it seems that when more than a moderate proportion of herbs is present (say 10 per cent), the advantage of an increased mineral content is offset by a decreased yield of dry matter and a lowering of protein digestibility. In a preliminary paper [2] the point is made that the sodium content of pastures of the Cockle Park type is often insufficient to support more than the requirements of 2 gal of milk in addition to maintenance; but although herbs contain more than twice as much sodium as the Cockle Park mixtures, the work reported in [1] did not consistently demonstrate the superiority of herb-rich swards in this respect. However, lack of sodium is in many instances a limiting factor in milk production and it can only be countered satisfactorily by supplying salt licks or some other form of mineral supplementation.

Salt can control Concentrate Consumption

In certain parts of the U.S.A. it is becoming a practice to control the consumption of concentrates by cattle on free range (Oklahoma) and on irrigated pastures (California) by mixing in considerable quantities of salt. For example, fattening steers will eat about 1 lb of concentrates per 100 lb live weight when salt is present at the rate of 8 to 10 per cent, and improvement or depreciation of the pastures can be compensated by increasing or decreasing the proportion of salt in the concentrates. The less salt, the more concentrates will be eaten; and vice versa. The effect of different levels of salt upon the health of the animal, the digestibility of the food and the carcass grade have also been reported [3, 4].

In one set of experiments [3] sheep were fed rations with salt contents varying from 0.66 to 12.8 per cent. There were no statistically significant differences in digestibility of protein, in carcass quality or in worm burden. With steers, there was possibly a slight loss of carcass quality on the high salt rations. At another station 6 per cent salt in a ration did not significantly affect digestibility in the steer, but reduced it slightly in wethers. From these studies and other work it is concluded that high salt rations do not produce any serious physiological disturbances in ruminants, and any slight loss in efficiency of food utilization is negligible, in view of the saving gained by automatic self-rationing.

Reducing the Incidence of Milk Fever

A contribution to the literature on milk fever deals with the effect of low-calcium, high phosphorus rations before calving [5]. Three rations were tried:

(*a*) 8 lb oat hay, 8 lb concentrates (with 1.5 per cent monosodium phosphate) supplying 11 g calcium (15.4 g as CaO) and 44 g phosphorus (101 g P_2O_5).
(*b*) 8 lb oat hay, 8 lb concentrates (with 5 per cent monosodium phosphate) supplying 11 g calcium (15.4 g CaO) and 74 g phosphorus (170 g P_2O_5).
(*c*) 5-6 lb oat hay, 10-12 lb concentrates (with 5 per cent monosodium phosphate) supplying 8.5-10 g calcium (12-14 g CaO) and 88-102 g phosphorus (202-235 g P_2O_5).

The experimental rations were fed from about one month before calving to cows that had all calved at least twice previously, and were from high-yielding Jersey herds where the incidence of milk fever had been high. After calving, normal dairy rations were fed.

Results were as follows:

Ration	Number of Cows	Number showing Milk Fever Symptoms	Number which showed Milk Fever Symptoms after previous Calving
(*a*)	26	2	5
(*b*)	19	2	10
(*c*)	28	1	12

It was suggested that the low calcium diets might act by stimulating the parathyroids to mobilize calcium from the bones, thus preventing a

drop in blood calcium following the onset of lactation. The treatment did not significantly affect milk yield and it was considered that the duration of the treatment, one month in the dry period, would not seriously deplete calcium reserves since the latter part of lactation and the normal dry period are times of calcium storage. This postulates, of course, that ample calcium is fed at other times.

Combating Parakeratosis

The occurrence of a skin disease in pigs characterized by reddened incrustations (particularly in the region of the hocks, thighs and under belly), and by fissures running through areas of thickened skin, has been described. This condition, known as parakeratosis, has been related to deficiency of zinc, either absolute or conditioned by excess of calcium [6, 7]. There is evidence also that it is more likely to occur when dry feeding is practised. The results of one of the trials [7] are given below; in each of four lots there were ten pigs and the feeding continued for eight weeks:

Lot No.	*Ad Lib.* Feeding of:	Average Initial wt.	Average Daily Gain	Feed per lb Gain	Number with Dermatosis
		lb	*lb*		
1	Ration A	27.9	0.54	3.95	10
2	A+20 p.p.m. zinc	27.9	1.06	3.02	1
3	Ration B	27.9	0.91	3.23	3
4	B+20 p.p.m. zinc	28.0	1.25	2.86	0

A contained 1.50 per cent Ca (2.1 per cent CaO), 0.80 per cent P (1.84 per cent P_2O_5) and 31 p.p.m. zinc.
B contained 0.98 per cent Ca (1.37 per cent CaO), 0.70 per cent P (1.61 per cent P_2O_5) and 29 p.p.m. zinc.
They did not differ in other respects.

At the end of the eighth week all the pigs in lot 1 were put on the same ration as lot 2 and during the next six weeks the average daily gain was 1.54 lb; the skin lesions took from three to six weeks to disappear. It has now become quite normal practice to fortify pig foods with about 4 oz zinc carbonate per ton, which represents an addition of about 60 p.p.m.

Copper Metabolism

A case of copper poisoning in rams is reported [8]. Each animal was receiving daily 2-3 lb of concentrates to which had been added a proprietary mineral supplement containing 1,300 p.p.m. of copper. This treatment had been given for a year apparently without harm, but some days after a nicotine-copper sulphate worm medicine had been given several rams were attacked by a feverish illness which resulted in seven deaths. Post-mortem examination showed large accumulations of copper in various organs. A warning is given against a too prolonged medication with copper, especially if there should be occasional extra medication. Copper poisoning has also been recorded in sheep grazing in orchards

sprayed with copper preparations [9]. The inter-relationship of copper with other minerals has been the subject of Australian work. In preliminary work it had been noticed that different results were obtained when small quantities of copper and molybdenum were added to lucerne hay or oat hay (or various proportions of these in a mixture) and fed to sheep. The lower the proportion of lucerne, the more copper was stored in the liver. Hence, some factor in lucerne allowed molybdenum to affect copper storage. This factor was found to be inorganic sulphate which was present to the extent of 0.3 per cent in lucerne hay but only to 0.05 per cent in oat hay. When sulphate was added to the oat hay to bring the amount up to that of the lucerne, both hays reacted similarly towards copper. The following data, freely modified from one of the papers in the series [10], illustrate the findings:

Feedingstuff	Daily Intake			Change of Liver Copper	
	Copper	Molybdenum	Sulphate		
	mg	*mg*	*g*		
Lucerne hay and copper	9.8	0.5	2.2	+ 20	Change expressed as mg copper in whole liver after 114 days.
Lucerne hay and copper and molybdenum	9.8	10.5	2.2	− 12	
Oat hay and copper	10.0	0.3	0.35	+ 54	
Oat hay and copper and molybdenum	10.0	10.3	0.35	+ 40	
Lucerne hay and copper	10.1	0.7	2.2	+250	Change expressed as p.p.m. of copper in liver dry matter after 82 days.
Lucerne hay and copper and molybdenum	10.1	11.1	2.2	− 75	
Oat hay and copper and sulphate	9.9	0.5	2.2	+128	
Oat hay and copper and sulphate and molybdenum	9.9	10.7	2.2	− 75	

This interesting work suggests that molybdenum in herbage is only likely to interfere with copper metabolism if it is accompanied by an appreciable amount of sulphate, and investigations of possible copper deficiencies in livestock should now obviously include work on several other components including sulphate.

Support for this view is mounting, and a recent paper [11] is typical. Molybdenum or sulphate, or both, were added to various portions of a basal ration containing 5.2 p.p.m. of copper; the concentrations of the three components in the last case were similar to those in natural pastures causing swayback (enzootic ataxia), steely (dystrophic) wool and white-banding (hypochromatrichia) of black wool. Each group contained six or seven sheep.

Group	Composition of Diet			Liver Copper (mean of group) (p.p.m. of dry matter)			
	Cu	Mo	SO_4	Before Expt.	At 17 weeks	At 30 weeks	At 50 weeks
	p.p.m.	*p.p.m.*	*per cent*				
1	5.2	0.83	0.04	254	169	236	—
2	5.2	5.14	0.40	222	45	25	13
3	5.2	5.14	0.40	203	39	19	9
4	5.2	5.14	0.04	306	181	170	—
5	5.2	0.83	0.40	230	93	70	50
	Significant difference (P=0.05)				55	60	28

Where the sulphate remained low (Groups 1 and 4) the liver copper was not reduced too far, but where it was high and molybdenum also was high (Groups 2 and 3) the level of copper dropped into the danger region. High sulphate by itself (Group 5) reduced the copper to about a border-line value. Some swayback pastures have been known to contain only about 1 p.p.m. of molybdenum; it would be very interesting to know their inorganic sulphate content.

Copper and Iron Utilization

The form in which copper occurs in herbage and its availability to the animal have been the subject of recent study [12]. It was found that not only does most of the copper exist as organically-bound complexes but also that ionic copper (added as sulphate) is quickly bound in such complexes which are only decomposed at a pH of 2.0 or less. Further, it appears that these complexes are more easily absorbed from the intestine than is inorganic copper and that they evoke a more rapid physiological response [13]. The work failed to demonstrate any difference between the responses to "swayback" and "normal" herbage when these were fed to copper-deficient rats.

In a study of the utilization of iron (as shown by haemoglobin levels) in young pigs [14], it was found that pigs reared indoors and receiving iron by mouth each day from the fourth to the tenth day had only about three-fourths as much haemoglobin at weaning as pigs reared outdoors and receiving no iron treatment. The difference was ascribed to the greater vigour of the outdoor pigs causing a greater consumption of creep-feed containing iron. At weaning they were taking one-and-a-half times as much creep-feed as the indoor pigs and they weighed one-fifth more.

Cobalt Dosage for Hill Sheep

It is well known that cobalt is best applied to pining land along with superphosphate. Two lb of cobalt sulphate per acre is sufficient for three or four years, but there may sometimes be practical difficulties in satisfying the need with sheep on hill land. For instance, the topography of

the land may make it impossible to apply cobaltized fertilizer by machine, and the extent of the area and the low rate of stocking may make application by hand uneconomic. Again, it may not be possible to get the sheep to take minerals from troughs. In such circumstances, cobalt must be given by hand, but where small doses are concerned its efficiency depends on frequency of administration. Thus it has been found [15] that while lambs grazing cobalt-dressed pastures gained 57 lb in three months, and lambs getting 1 mg cobalt daily or 7 mg weekly, gained 56 and 52 lb respectively, yet 14 mg fortnightly or 28 mg per 28 days gave increases of only 39 and 30 lb respectively—not much better than the 27 lb gained by untreated lambs. Obviously, daily or even weekly gatherings were out of the question, but since monthly gatherings were quite normal practice it was decided to give 250 mg of cobalt on each of four occasions at intervals of one month. This resulted in gains of between 90 and 95 per cent of those obtained on dressed pastures. The total cost of the cobalt was 2*d.* per lamb. The rate of 250 mg (i.e. 1 g cobalt chloride) per dose showed no sign of being dangerously excessive.

The Riddle of Hypomagnesaemia

One of the most discussed elements is magnesium. The disturbance of magnesium metabolism, resulting in hypomagnesaemia with manifestations in grass tetany or "staggers", is of fairly common occurrence. Many explanatory articles have been written, a few of which are listed [16], but these show that the condition is very complex and that several differing theories are held. Some continental workers incline to the view that excessively high potassium in herbage may be a main cause, acting by producing an alkaline state of the blood unfavourable to the normal concentrations of calcium and magnesium and by replacing sodium in body fluids [17]. A suggestion from English workers is that the high protein content of young grass which has been heavily fertilized with nitrogen gives rise to a large amount of ruminal ammonia which possibly interferes later with magnesium absorption in the intestine [18]. It is known, however, that hypomagnesaemia can occur on winter feeding when the factors mentioned above do not operate, and it must be admitted that the primary cause is still obscure. A recent review [19] discusses the inadequacies of current hypotheses and emphasizes the need for further investigations. Fortunately, empirical treatment with magnesia (calcined Magnesite) has been established as being of some value and is now routine on many farms. It is generally agreed that the use of magnesium supplements should be intermittent, not continuous. They should be applied for a few weeks only before a major change of feeding or management and be discontinued a few weeks after the change. The Dutch suggestions to supply common salt at danger times and to feed sugar beet pulp and roots on account of their favourable mineral composition might also be of value. The beet pulp would have the additional advantage of supplying fibre for butterfat to cows at young spring grass.

Experience of hypomagnesaemia in suckling herds in November and December, when the cattle were kept outdoors on sparse herbage without supplementary feeding, prompted an investigation [20] into the effect of extra food supplies in such conditions. One lot of cattle was kept indoors on hay and concentrates, while another lot was left outdoors without a food supplement. Blood magnesiums were similar in both groups until mid-October, but thereafter the level fell in the outdoor group and reached the danger zone in early November. The introduction of a small amount of hay, raised over three days to 16 lb, caused an increase in the blood magnesium, and a safe level was attained after a week or so. The increase was maintained, but more gradually, over the next month until the two groups were almost level again.

Hypomagnesaemia in beef calves suckled for some months but receiving little or no supplementary feeding has also occurred [21]. The cause was a straightforward dietary deficiency, milk being a poor source of magnesium. The trouble could be prevented by giving about 2 g of magnesium carbonate daily to each calf, although this quantity was insufficient for calves over two months of age. The ratio of calcium to magnesium in the bones of the affected animals was 90 to 1 or more; in normal calves it was 60 to 1 or less.

Various attempts have been made to ensure an increased magnesium intake through grown food rather than by direct supplementation, although it should be said that there is little evidence that hypomagnesaemia is due to an insufficient supply of the element in the food (excepting, of course, an exclusively milk diet as already mentioned). Pastures have been dressed with magnesian limestone or magnesium sulphate in an effort to raise the percentage of magnesium in the herbage, but the results have been conflicting—some workers found a positive effect and others none. A positive result [22] was obtained on a farm where 2 tons of magnesian limestone (20 per cent MgO) per acre increased the magnesium content of the herbage to one-and-a-half times that of untreated herbage or herbage treated with ordinary limestone. Further, there was some indication that the blood magnesiums were higher in cows pastured on the magnesium-treated field. Applications of magnesium sulphate to growing herbage and to herbage being filled into a silo have been tried [23], but it was found that the effect on herbage was transitory and the cost excessive; treated silage appeared to maintain the blood magnesium while it was being fed, but the effect was lost when the animals went out to grass. At present, the best treatment seems to be direct feeding of a magnesium supplement, but if the land needs lime, application of a magnesian type might be advantageous.

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S.M.B.

Crop Husbandry

The Effect of Date of Planting and other Factors on Potato Yields

It is well known that the date of planting influences the yield of the crop, and the critical date varies to some extent from season to season. The extent of the effect of planting dates on the yield of main-crop potatoes, based on data obtained from the N.A.A.S. potato survey 1948-50, and experiments carried out at various centres in this country from 1946-51 is reported on by G. V. Dyke of Rothamsted Experimental Station. ("The effect of date of planting on the yield of potatoes". *J. agric. Sci.*, 1956, **47**, I, 122-8.)

In the experiments carried out at various centres, planting dates varied from mid-March to early June. Up to about 10th April there was little loss of yield due to delayed planting, but from that date onwards there was a steady decline in yield of about 6 cwt per acre per week until about mid-May, after which date the decline was even more rapid.

Most of the crops examined in the N.A.A.S. potato survey were planted between mid-March and mid-May; a few were planted after 19th May. Results of both the survey and the experiments show a general decrease of yield with late planting. After about mid-April, the loss of yield increased for each succeeding week's delay in planting, and amounted to as much as 50 cwt per acre for the few crops planted after 19th May.

The evidence obtained in both the survey and experiments shows that yields are decreased by delay in planting after mid-April at the rate of about 8 cwt per week. The decrease is greater in seasons when conditions are suitable for early planting, and also on high-yielding fields.

Information from the 1945-50 Rothamsted experiments on the relation between date of planting, and the effects of dung and fertilizers is summarized in the following table of the report. The variety used was Majestic.

Date of planting potatoes at Rothamsted, 1945-50
Mean yields and effects (*tons per acre*)

Mean date	3rd April	23rd April	12th May	31st May
Mean yield	10.04	9.15	8.66	7.32
Effects:				
Dung.	3.59	2.97	2.40	1.68
N	1.80	1.02	1.08	.72
P	.80	.78	.44	.42
K	2.07	.61	.86	.38

In these experiments the responses to dung and fertilizers were all greatly reduced when planting was delayed. Between the early April and late May plantings the responses to dung, nitrogen and phosphate fell by 50 per cent, while the response to potash was reduced by 80 per cent. Other yield data of the Rothamsted experiments show that the loss due to late planting is less from a poorly manured crop than from a well-manured one.

The date of planting experiments at Craibstone and Rothamsted included a comparison of chitted and unchitted seed. At Craibstone the comparison was carried out for more than one year. At this centre chitted seed increased yields by $1\frac{3}{4}$ tons per acre for March plantings, and by $2\frac{1}{2}$ tons per acre for plantings in mid-April and later. In the one experiment at Rothamsted in 1945, there was only a slight increase in yield due to chitting for the two earlier plantings (30th March and 20th April), but when plantings were delayed until 11th May or 1st June, the chitted seed yielded over 1 ton per acre more than the unchitted seed. It will be seen that the evidence from the experiments at these two centres is somewhat conflicting as to yield responses from chitted seed when planted early. On the other hand, at both centres the experiments show that loss of yield due to late planting may be made up to some extent by the use of chitted seed. At Craibstone, chitted seed planted on 1st May yielded as heavily as unchitted seed planted in March. The author points out the need for more information on the value of chitted seed in relation to conditions in England and Wales.

Finally, the author comments that if all fields were planted by mid-April, the potential increase in the national production of potatoes would be equivalent to about 10 cwt per acre.

Spring Grazing of Winter Oats

Spring grazing of winter-sown cereals is a common practice on livestock farms in most parts of the country. In recent years the effect of spring grazing on winter wheat grain yields has been studied, but for various reasons there has been less work on winter oats. However, spring grazing of winter oats will probably become more common, and a recent paper on the subject is of particular interest. ("The effects of winter and spring defoliation on the subsequent yield of grain and straw of S.147 oats". G. M. Davies. *J. agric. Sci.*, 1956, **47**, III, 363-6.)

In these North Wales experiments during the three years 1950-2, the three treatments were: winter defoliation in mid-December, spring defoliation in mid-April and no defoliation. All three treatments were compared without and with a top dressing of $1\frac{1}{2}$ cwt of sulphate of ammonia per acre given immediately after the spring grazing. The oats were sown during the latter half of September. Sheep were grazed, since the aim was to leave $\frac{3}{4}$ in. and 1-$1\frac{1}{2}$ in. respectively of herbage after the winter and spring grazing.

Dry Matter Yields

Seasonal variations in the yields of dry matter available for both the winter and spring grazings were considerable. These appeared to be related to the amount of winter (November-January) rainfall; the highest amount of dry matter was produced during the season of lowest winter rainfall. The dry matter available for the winter grazing varied during the three seasons from 64-179 lb per acre, with a mean yield of 107 lb per acre. On the other hand, the dry matter available for the spring

grazing varied from 584-1,109 lb per acre with a mean yield of 727 lb per acre.

Grain and Straw Yields

The mean yields of grain and straw from the various treatments are summarized as follows:

Mean Yields of Grain and Straw, 1950-52

	No Defoliation	Spring Defoliation	Winter Defoliation
	cwt per acre	*cwt per acre*	*cwt per acre*
		GRAIN	
Without Nitrogen .	21.1	19.3	15.6
With Nitrogen .	23.0	21.1	16.6
Mean . . .	22.1	20.2	16.1
		STRAW	
Without Nitrogen .	37.8	29.2	27.0
With Nitrogen .	47.2	35.7	33.0
Mean . . .	42.5	32.4	30.0

Winter Grazing

After winter grazing there was a mean loss of 6 cwt of grain and 12½ cwt straw per acre. The subsequent nitrogenous top dressing increased the grain yield by 1 cwt, and the straw yield by 6 cwt per acre compared with the grazed plots which were not top dressed.

Spring Grazing

This resulted in a mean loss of approximately 2 cwt of grain and 10 cwt of straw per acre. Compared with the grazed plots which were not top dressed, the nitrogenous top dressing increased the grain yield by 1.8 cwt and the straw yield by 6.5 cwt per acre. Furthermore, the grazed plots which were top dressed produced a grain yield equal to, and a straw yield only 2 cwt per acre less, than the plots which were not grazed and received no top dressing.

Protein Content

Analysis of the dry matter showed that the forage available for both the winter and spring grazing was a protein-rich food, although the protein content varied from season to season. During the three years, the crude protein in the dry matter of the winter and spring grazing varied from 26.8 per cent to 28.4 per cent and from 17.4 per cent to 23.1 per cent respectively.

Conclusions

From these experiments with S.147 oats it would seem that as far as *winter* grazing is concerned, although the small amount of keep offered is rich in protein and available at a time of scarcity, its value is far out-

weighed by the reduced yield of grain and straw which follows, a reduction which cannot be made good by subsequent top dressings of nitrogen. On the other hand, the timely *spring* grazing of S.147 can provide a substantial amount (equivalent to about 200 sheep grazing days per acre) of relatively high-protein animal keep, and if a nitrogenous top dressing is given after grazing, the grain yield can be as satisfactory as that from a similar ungrazed crop which receives no top dressing. On land where S.147 is likely to lodge, the reduced straw yield resulting from spring grazing would not be a disadvantage, and the keep available would be particularly valuable in a season when the growth of spring grass is late.

Similar data about other varieties and from areas where winter oats are a more reliable crop than where these experiments were carried out, would be valuable to many livestock farmers.

C.K.

Farm Management

Variations in Farm Organization and Management

Methods of diagnosing weaknesses in the management of farms were outlined in earlier issues of this REVIEW [1]. The procedures (all basically similar with minor variations of technique) compared the costs and returns relating to an individual farm with "production standards" derived from the accounts of farms which were similar in size and type of organization. Tables of such comparative measures of performance are now prepared regularly at the various University Departments of Agricultural Economics and are becoming a familiar aid to advisory work in farm management. The usefulness of these comparative standards is further enhanced by an analysis of the causes of differences in the success of individual farmers [2] on arable, mixed, upland and lowland dairying farms.

Arable Farms

On the arable farms in S.W. Lancashire, about one-third of the variation in Investment Income per acre, i.e., net farm income less the value of the farmer's own labour, could be accounted for by differences in the proportion of high output cash crops (potatoes, sugar beet, peas and vegetables). It was clearly advantageous to increase the proportion of the farm devoted to these crops, within the limits of good husbandry, and provided that seasonal supplies of labour were available. It does not follow, however, that an increase in the proportion of high output cash crops would be automatically accompanied by an increase in net income per acre. Not all farmers are equally efficient in the management of these particular crops and their skill could also vary in looking after

other crops and livestock enterprises; but very few farmers achieved a high net income per acre when the proportion of high output cash crops was low. To increase this proportion, additional crops were generally introduced rather than the potato area being increased. In this way, the intensively operated farms have been able to avoid, very largely, the danger of disease. The resultant intensification of the farming system requires a high degree of technical management, and a greater outlay of resources, particularly of labour and fertilizers. High yields, attained by using adequate fertilizers and proper cultivation practices gave a good return and higher net incomes.

Mixed Farms

On mixed farms reasons for variations in net incomes were more difficult to determine because of the wide variety of enterprises but, on such farms, there were wide differences in the labour productivity which could only be fully explained by varying efficiency of labour management. It was found that a high output per man did not only depend upon the speed and efficiency of the worker but also upon a high standard of general management which ensured that labour was working on profitable enterprises. On many of the larger farms the reason for a low labour productivity lay in the low output of the stock area of the farm—many of the larger farmers managed their cash crop much better than their stock; often because they had too many livestock enterprises, each not large enough to carry its own staff.

Although it is commonly asserted that from mixed farms cash cropping yields a higher profit per acre than does land devoted to livestock production, on the farms included in this study, chances of earning profits from land devoted to dairying and subsidiary enterprises or from a farm wholly devoted to the production of cash crops were about equal. The way in which the cash crop acreage was managed had a much more important effect on income. Farms which obtained a high output per acre from cash crops (by obtaining high yields and growing intensive crops such as potatoes and sugar beet) were, in general, the farms making the higher profits. Reasons for low profits attributable to livestock enterprises are discussed in more detail in the next paragraph.

Dairy and Livestock Farms

Low net incomes on dairy and livestock farms were mainly due to two faults in organization—either low output per acre or excessive costs of producing a reasonable level of output. A low output per acre was usually due to one or more of the following factors:

(*a*) light stocking;
(*b*) a high proportion of less profitable animals, such as young stock;
(*c*) only small numbers, or no pigs and poultry;
(*d*) low yield per unit of livestock, e.g., milk yields.

Poor utilization of the total available feed was usually the reason for

excessive costs. Feed utilization could be improved by:

(*a*) raising the level of technical efficiency in the feeding of concentrates by weighing and rationing feed; avoiding waste and balancing feed nutrients more closely with the requirements of stock;
(*b*) mixing rations on the farm from "straight" rather than the relatively expensive "compounds"; and
(*c*) increasing production from the farm acreage to reduce the quantity of feed purchased.

In practice, it was found that when grassland was improved there was seldom a reduction of purchased feed, but the greater productivity enabled more and better quality stock to be kept.

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The Use of Antibiotics in the Control of Plant Diseases

IN RECENT YEARS, considerable progress has been made towards controlling a number of plant diseases by the systemic or protective use of antibiotics. The first-known antibiotics, such as penicillin, are active only against gram positive bacteria and few plant pathogens belong to this group. The discovery of streptomycin, which is active against both gram positive and gram negative bacteria has enabled rapid developments to take place in the control of bacterial diseases of plants, particularly in America. There, a number of workers [1, 2, 3, 4 and 5] have obtained a good control of the tobacco wildfire disease, caused by *Pseudomonas tabaci*, by the application of sprays containing 100-200 p.p.m., and dusts containing 0.2 per cent streptomycin. Not only was the treatment effective as a protective spray, but the higher concentrations successfully eradicated the disease after it was established in plant beds. The results indicate that streptomycin is more effective than the copper drench sprays used up to the present.

Similarly, in large-scale field experiments in California over the last three years [6 and 7], spraying pear blossom with either streptomycin alone, or mixed with another antibiotic, terramycin, has given a good control of the fireblight disease caused by *Erwinia amylovora*. The antibiotic sprays have a great advantage over copper sprays because the latter are liable, under certain climatic conditions, to cause severe russetting of the fruit. The mixture of streptomycin and terramycin known as agrimycin has also been successfully used by Conover [8] to obtain an economic control of bacterial spot (*Xanthomonas vesicatoria*)

on tomato. The same bacterium also causes a leaf spot of pepper, but Crossan and Krupka [9] found that agrimycin applied as a foliage spray was not absorbed by the pepper leaves and had no eradicant effect when the bacterium was established within the leaf. It did, however, function as a protectant, and infection was reduced by frequent spraying.

A similar effect was obtained by Gray [10] with bacterial blight of beans caused by *Xanthomonas phaseoli*. He found that the addition of 1 per cent glycerine to streptomycin sprays considerably enhanced their effectiveness, and this was correlated with an increase of absorption of antibiotic by the bean leaves. Ark and Alcorn [7] also discovered that the efficiency of streptomycin dusts was influenced by their formulation. When bentonite was used as a carrier, results were variable, apparently due to the difficulty with which the antibiotic was released from the dust particles. The addition of 1 per cent K_2HPO_4 to the bentonite, or the use of a pyrophyllite base resulted in increased absorption of the antibiotic by pear leaves and blossoms, thus giving improved control of fireblight in the field.

This absorption of streptomycin by plants is not without danger. Several workers have noted chlorosis in the host plant when concentrations of 50 p.p.m. have been used. An accumulation of streptomycin after its injection into pear trees by Ark and Alcorn [7] resulted in the development of chlorotic leaves and flower buds the following year. Pramer [11] has also demonstrated that streptomycin is extremely stable when absorbed by cucumber seedlings and that it tends to accumulate in the upper parts. Further study of this effect in food crops is therefore needed to safeguard the consumer.

Another antibiotic, aureomycin, has been shown by Sutton and Bell [12] to control black rot (*Xanthomonas campestris*) of swedes. This was achieved by soaking the seed for 30 minutes in 1,000 p.p.m. and then drying for three days before sowing. Other antibiotics such as polymyxin and tetracycline have been shown to be active against plant disease bacteria, but so far have not been successfully applied to plants.

Antibiotics v. Fungi

Progress with the control of fungal diseases by antibiotics has not been so rapid, but promising results have been obtained by a number of materials. Brian and his co-workers [13, 14 and 15] have demonstrated that griseofulvin, a metabolic product of three species of *Penicillium*, has a remarkable effect on distorting the mycelial growth of a number of parasitic fungi. They have also demonstrated that this substance may be absorbed by the roots of a large variety of higher plants and translocated through them without any harmful effect [14, 15 and 16]. In sand and water culture experiments, griseofulvin has given a good control of Chocolate Spot (*Botrytis fabae*) on broad beans [14], Grey Mould (*Botrytis cinerea*) on lettuce [14 and 16], powdery mildew (*Erisyphe graminis*) of barley [16], and early blight (*Alternaria solani*) of tomato [16 and 17]. Unfortunately, there are still unsolved problems in con-

nection with its practical application. Jefferys [18] found that griseofulvin broke down rapidly in soil, and Stubbs showed that it was less effective as a foliar spray than when absorbed by the plant roots. More recently, Davis and Rothrock [19] have shown that in spite of this, griseofulvin offered considerable promise in greenhouse tests when used as a foliage spray against alternaria blight of tomato.

Actidione produced by certain strains of *Streptomyces griseus* has considerable fungicidal properties and has proved effective against powdery mildews of bean, rose and grape. It tends to be toxic to the host plant, but Wallen [20] found that it gave an excellent control of stem rust (*Puccinia graminis*) of wheat and that the wheat plants recovered from the leaf injury caused by the spray and outyielded unsprayed controls. It has also been used successfully in conjunction with captan as a seed treatment for controlling bunt (*Tilletia caries* and *T. foetida*) of wheat [21].

Canidicidin, a product of another strain of *Streptomyces griseus*, was discovered by Lechevalier and his co-workers [22]. They found that at a concentration 0.15-0.3 g per ml it completely inhibited growth of *Ceratostomella ulmi*. Alcorn and Ark [23] used it successfully as a dip for peach fruit to protect them against brown rot (*Monilinia fructicola*). The same workers [7] also demonstrated that if it was applied to wheat plants at a strength of 1:5,000 it protected them against subsequent inoculation by spores of stem rust strain 15B applied later. It also gave a complete control of bean rust (*Uromyces phaseoli*), and was fairly effective against antirrhinum rust (*Puccinia antirrhini*).

Leben and Keitt [24] found antimycin to be very effective against the apple scab fungus, *Venturia inaequalis* and reported that yet another antibiotic helixin was effective against a number of seed-borne cereal diseases [25].

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H.E.C.

Provincial Note

Wales—A Livestock Country

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WALES, with a total area of about five million acres, is traditionally a livestock country, and livestock, including its products, account for a very high proportion of the Welsh farmer's income. Indeed, on many farms the whole annual income is obtained from livestock alone.

On most Welsh farms, only a very small area is devoted to the production of crops for direct sale; these cash crops are usually specialized or horticultural crops and are confined to limited areas. This does not mean that farmers in Wales are not capable husbandmen, but historically they were stock-keepers before they began tilling the soil, and cropping has always remained complementary to the livestock policy. In addition to this inherited tendency to be stockmen rather than ploughmen, there are other reasons why Welsh farming has remained primarily livestock. The two most important factors are the nature of the country and the climate. "Bryn a Cwm", or hill and coombe, were never very inviting to ox or horse ploughing. Fields are steep and often inconveniently shaped owing to the slow, haphazard progress of reclamation upwards from the valleys. Nearly as formidable is the problem of climate—the high rainfall makes both hay and corn harvest hazardous in eight seasons out of ten. Much has been done to overcome this climatic risk by silage-making and the introduction of early-ripening varieties of crops, etc.; progress in artificial drying may play an important part in the future. However, the weather provides at least one blessing; it creates favourable conditions for growing grass, and this is the fundamental reason for the pastoral nature of the country.

Changing the Face of Wales

Despite the conditions which dictate that Wales must be a country of pasture, Welsh farmers completely changed the pasture-tillage pattern during the last war. The following table gives the changes *in ratio* between permanent pasture, temporary pasture and tillage in the years 1939, 1947 and 1953:

	Permanent Pasture	Temporary Pasture	Tillage
1939 . . .	9	1	1
1947 . . .	4	1	3
1953 . . .	3	1	1¼

These figures show that for every 110 acres of agricultural land in 1939, 90 acres were in permanent pasture. In 1947, half the land was in temporary pasture or tillage and only half in permanent grass. Today, ten years after the war and some years after the allocation of cropping and tillage targets, the ratio of tillage to temporary pasture is similar to that of 1939, but temporary pasture now represents a quarter of the grass area instead of a tenth as in 1939.

While this reduction in permanent pasture was taking place, and despite feedingstuffs rationing and all the other restrictions of war, the cattle population increased by 20 per cent between 1939 and 1945 and the drop in the number of sheep was very small, only 4 per cent. The tragic winter of 1947 seriously reduced sheep numbers, but by 1953, during a period of attractive prices, 50 per cent of the losses had been made good.

Various Drawbacks

Although Wales is a pastoral country, some of the conditions are unfavourable to livestock production. In general, the soil is not inherently very fertile and large areas are deficient in lime and other bases. Such soil is associated with a variety of mineral deficiency troubles in stock. Nature was not very kind in its final distribution of soil over the whole area: the net result of the various geological upheavals and glaciation was to leave only half the country—2½ million acres—as what we now call "agricultural land". The other half is mainly rough grazing—common or privately owned—which varies in quality but includes a large proportion of bare mountain tops. In addition, large areas of the country are very high up; 27 per cent of the total area is over 1,000 ft and a further substantial percentage lies between 500 and 1,000 ft. The altitude of the land and its barren nature has an adverse effect on intensity of stocking and rate of production, even with hardy breeds of stock.

Wales is often called a country of small farms, and the size of a farm does, of course, have an effect on farming efficiency. It is difficult to keep labour fully employed to sow and harvest "on time" with possibly inadequate or shared machinery which may not be available at the right time, or to sell stock to the best advantage, etc. The economy of the small farm is receiving much attention at the present time, and its problems are now very different from what they were when a whole village, men and women, turned out to help on the land when they were needed.

The small farms in Wales include not only the lowland and marginal farms, but also many of the upland farms that carry hill flocks. This, perhaps, one would not expect in a country which has one sheep per acre and an extensive area of rough grazing. The following table, taken from Ashby and Evans' *The Agriculture of Wales*, shows the size range of hill flocks. The figures relate to ewes and shearlings which qualified for the hill sheep subsidy in 1942:

Size Range of Flocks	Per cent of Hill Flocks (*Ewes and Shearlings only*)	Per cent of total Sheep in Hill Flocks
1—50	35.29	11
51—100	29.15	17
101—200	21.74	26
201—1,000	13.46	41
1,001 and over	.36	5

Intensity and Pattern of Stocking

Progress in agricultural knowledge, particularly as regards soils, fertilizers, seeds mixtures, grassland management and livestock husbandry, has greatly influenced the intensity of stocking on Welsh farms. This is very clearly shown by the following figures of stocking for 1867 and 1955:

	1867	1955
Total Cattle . .	580,000	1,000,000
Total Sheep . .	2,410,000	4,500,000
Total Pigs	249,000	208,000

It is evident from these figures that Wales concentrates on grass-eating animals and that the number of cattle and sheep has practically doubled in the last ninety years. The ratio of cattle to sheep (1:4½) has remained practically unchanged over the last century.

Pig population has remained static over this period. A study of the annual stock figures since 1867 shows the usual ups and downs, but no expansion. The lowest total (80,000) was recorded during the last war; the 1918 total (158,000) being the second lowest.

These figures show not only the progress made in numbers of stock, but also the degree of intensity that has been achieved. The average stocking over the country as a whole is equivalent to one head of cattle per 2½ acres of agricultural land and one sheep per acre over the total area (agricultural land plus rough grazing). Ashby[7] quotes figures for 1927 which confirm this intensive stocking and show that Wales carried 29.7 cattle per 100 acres of cultivated land, compared with 23.9 in England and 25.8 in Scotland.

Breeds

Wales claims one native breed for each of the main classes of farm stocks; for horses there is the Welsh Cob; cattle, the Welsh Black; sheep, the Welsh Mountain, and pigs, the Welsh Pig. This probably means that at one time the farming followed a fairly uniform pattern throughout the country. Local variations within the Welsh breeds gradually developed until, in cattle and sheep, there were distinct North and South Wales types. In the course of time, this uniform pattern has been changed by economic factors, specialization in production, the work of Breed Societies, improved knowledge and even changing individual tastes.

CATTLE

It is in cattle that the changes in breeds have been most marked, and this is the result of public demand. For example, the demand for beef caused the invasion of the mid-Wales border counties by the Hereford breed, and the demand for more milk led to the introduction into the dairying areas of breeds with "a bit of colour"—first the Shorthorn and later other dairy breeds. The following figures of bulls licensed in Wales give an idea of the trends in the past twenty years, especially of the swing towards dairying and the keen competition between breeds which is in progress:

Bull Licences Issued

Year ending 31st March	Ayrshire	British Friesian	Hereford	Shorthorn	Welsh Black	Total Licences Issued
1935	4	43	513	1,139	210	1,981
1945	202	1,303	404	2,270	323	4,592
1953	148	796	459	559	254	2,308

The pattern on the female side, and maps of the penetration of other breeds into Wales, can be seen in Report No. 6 (1955-6) of the Production Division of the Milk Marketing Board.

SHEEP

The sheep breeds tell a rather different story. In 1942 it was estimated that the Welsh Mountain sheep far outnumbered all others, and accounted for 89 per cent of the sheep population. The breeding stock has remained predominantly Welsh, while rams, particularly those of the Down breeds, are imported for crossing purposes in specialized fat lamb production. A survey of breeds, something on the lines of the Milk Marketing Board's work on cattle and covering sheep and pigs, would be both interesting and useful.

PIGS

The Welsh pig has made rapid progress in the last few years and the number of boar licences issued for this breed in 1953 was seventeen times greater than in 1947. Indeed, by 1953, one in six of the boar licences issued in Wales was for the Welsh breed. Many herds of Welsh pigs have been established outside Wales, and specimens of the breed have figured prominently at shows and competitions throughout England and Wales.

Production and Marketing

Throughout the years Wales has exported both livestock and livestock products. Under the old system of mixed farming, with store raising and butter-making as the main activities, there was an extensive trade in stock on the hoof over the border into England. With the growth of

towns, milk production expanded, and improved transport facilities led to Welsh milk finding a market in London and other areas in England. The depression of the late 1920s, and the setting up of the Milk Marketing Board, caused a further expansion of milk production. The most recent influence—the wartime demand for milk—has left few areas in Wales where milk collecting facilities are not available.

This year, of the 49,000 farms which are over 5 acres, 27,000 or 55 per cent are registered for milk production. The pattern varies from county to county; in Carmarthen and Flint 80 per cent of the holdings are registered for milk production, while in Radnor it diminishes to only 8 per cent. This means that there are large areas where store raising is still the main activity. The calf subsidy, the production of colour-marked calves, and the emphasis on beef have increased the number of store cattle raised. Some of these stores are sold for finishing in Welsh grazing areas, but many find a market in England.

As in other parts of the United Kingdom, beef production in Wales now aims at producing beef from grass, the animals being slaughtered at the lighter weights. Although the usual practice is to sell store cattle at about 18 months old, an extensive trade in 6-8 month-old stores has developed in mid-Wales since the war. These "weaned calves" are mainly Hereford type, born in the early spring, suckled on their dams and sold at organized sales in October. This trade is growing in popularity and is attracting buyers from many English counties. A recent publication by the Agricultural Economics Department, University College, Aberystwyth, *An Economic Study of Store Cattle Raising in Brecon and Radnor*, contains an interesting section, "Selling at 6 or 18 months", and describes the parts played by the type of farm and the hill cow subsidy.

In sheep production, the emphasis has almost completely moved away from "wethers" to the production of early fat lamb and mid-season lamb, but there is still a considerable store lamb trade. During the last few years more attention has been paid to the quality of draft ewes and, with the demand for grassland ewes of the "half-bred" type, much progress has been made with developing a "half bred" using the Welsh ewe. As with weaned calves, organized sales are held in the autumn. Demand is keen and reports from buyers over a wide area have been very promising.

The recent developments of the "weaned calf" and the "half-bred ewe" as additional outlets for the Welsh livestock are most encouraging and farmers in the areas concerned are showing a very keen interest in improving this trade.

Problems

Despite the advances that have been made, the Welsh livestock industry still has its problems. The basic one, how to grow and conserve crops and grass in sufficient quantity and quality to feed the stock for as much of the year as possible, is by no means new; nor is the related problem

of how to feed crops, grass and purchased foods to the best advantage. Some of these difficulties, inherent in the topography, soil and climate of Wales and the size of farms, have already been mentioned. In addition, there are the age-old problems of how to improve the quality and health of the stock and how to manage land, labour and capital to the best advantage.

It is interesting to note that the Rhuddlan Eisteddfod of 1850 offered a prize for the best essay on "The System best adopted for the Cultivation of the Uplands of Wales". In the middle of the last century there were similar competitions at other Eisteddfodau for essays on livestock, both breeding and management. Ample proof of the continued interest in the improvement of livestock is given by the number of Premium Bull and Premium Boar Societies operating in Wales and the excellent progress made in attestation.

Livestock has always been important in the agricultural economy of Wales. Rapid progress has been made in improving intensity of stocking and the quality of stock, but many problems remain unanswered. The experimental farms at Trawscoed and Pwllperian are investigating many of the long-term management problems, and the N.A.A.S. staff in the counties are showing farmers new techniques by means of demonstrations and experiments. These activities, together with fundamental research and the farm management approach to advisory work, are all tools to help the farmer to make the best possible use of his resources.

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